

AD 725509

FUEL OIL ASH CORROSION RESISTANCE OF ALLOYS  
60 Cr:40 Ni, 50 Cr:50 Ni and 10 Al:90 Fe

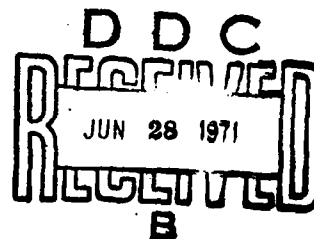
Evaluation Report  
NETL Test R-248  
NEM-013-120

23 October 1956

by

J. B. MC FARLAND

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ABSTRACT

Alloys 60 Cr:40 Ni, 50 Cr:50 Ni, 10 Al:90 Fe and 25 Cr:20 Ni were tested for high temperature corrosion resistance to synthetic fuel oil ash residues. Compared to Alloy 25 Cr:20 Ni, Alloys 60 Cr:40 Ni and 50 Cr:50 Ni had superior corrosion resistance after 100 hours at 1700 F. to both high vanadium and carbon bearing high sodium sulfate corrodents. Alloy 10Al:90 Fe had inferior corrosion resistance to both corrodent media. Resistance to scaling of 60 Cr:40 Ni alloy after 685 hours of prolonged air oxidation at 2000 F. was superior to 50 Cr:50 Ni and 25 Cr:20 Ni alloys.

SUMMARY PAGE

The Problem

To determine the relative high temperature corrosion resistance and scaling characteristics of alloys 25 Cr:20 Ni, 60 Cr:40 Ni, 50 Cr:50 Ni and 10 Al:90 Fe.

Findings

- a. Alloy 60 Cr:40 Ni had superior high temperature corrosion resistance to synthetic fuel oil ash residues and also superior resistance to high temperature scaling.
- b. Alloy 50 Cr:50 Ni had good overall corrosion and oxidation resistance.
- c. Alloy 25 Cr:20 Ni had inferior corrosion and air oxidation resistance.
- d. Alloy 10 Al:90 Fe had inferior corrosion resistance.

Recommendations

Service tests be conducted with "dog bone" superheater support sections fabricated from 60 Cr:40 Ni and 50 Cr:50 Ni alloys.

# ADMINISTRATIVE INFORMATION

Tests to determine the corrosion resistance of heat resistant materials to synthetic fuel oil ash residues were authorized in Bureau of Ships letter 819,9(347) Ser 347-135 of 2 Feb. 1956. A specific test, to determine the relative corrosion resistance of 60 Ni, 60 Cr:40 Ni, 50 Cr:50 Ni and 10 Al:90 Fe to synthetic fuel oil ash residues, was authorized by Bureau of Ships letter ADM/Naval (1956) NSS-051-087 Ser 347-139 of 15 February 1956.

Costs were charged to Project Order 60007/56. The index number is NSM-013-120.

This report covers part of an investigation of the high temperature corrosion resistance of materials and alloys to synthetic fuel oil ash residues.

NOT REPRODUCIBLE

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## REPORT OF INVESTIGATION

### Introduction

The Naval Boiler and Turbine Laboratory is conducting a research and development program to obtain metals or materials with superior high temperature corrosion resistance to synthetic fuel oil ash residues. This evaluation test represents a phase of this program.

### Description of Materials

Test materials were:

a. Alloy 50 Cr:50 Ni

Initial specimen was a 2" x 2" x 2-1/2" porous section of an ingot cast for experimental test purposes.

b. Alloy 10 Al:90 Fe

Initial specimen was 8" x 1-1/8" x 1/8" section of plate.

c. Alloy 60 Cr:40 Ni

Test specimens were cut from cast "dog bone" sections furnished for test.

d. Alloy 25 Cr:20 Ni

Control specimens of this material were machined from 1/8" wrought plate.

In order to obtain sound specimens from the spongy, porous section of 50 Cr:50 Ni alloy, specimen dimensions were reduced to 1/8" x 5/32" x 7/8". Other alloys tested were also machined to these dimensions. All test materials except the 25 Cr:20 Ni alloy were furnished the Laboratory by the Naval Shipyard.

# Method of Test

## a. Corrosion Resistance Tests

A set of test specimens of each alloy was weighted, partially immersed in corrosent mixtures contained in porcelain crucibles, and heated at 1700 F. in an electric furnace for increasing lengths of time up to 100 hours. Specimens were removed from the furnace at predetermined time intervals, descaled by combined mechanical and chemical cleaning, again weighed and percent weight loss determined. Test conditions were:

### Corrodents Used:

(1) High Vanadium - 5 G. (15%  $\text{Na}_2\text{SO}_4$  + 85%  $\text{V}_2\text{O}_5$ ).

(2) High Sodium Sulfate - Carbon Bearing 10 G. (90%  $\text{Na}_2\text{SO}_4$  + 10%  $\text{V}_2\text{O}_5$ )  
+ 4.3 G. Carbon.

### Time Increments for:

Corrosent (1) - 1, 2.5, 4, 6, 22, 46, 70 and 100 hours.

Corrosent (2) - 22, 46, 70 and 100 hours.

### Temperature - 1700 F.

Metals Tested - 25 Cr:20 Ni, 60 Cr:40 Ni, 50 Cr:50 Ni and 10 Al:90 Fe alloys.

Specimen Dimension -  $1/8" \times 5/32" \times 7/8"$ .

## b. Air Corrosion Resistance Test

Test specimens were placed in porcelain crucibles and heated in an electric furnace at 2000 F. for 685 hours. Samples were removed periodically, mechanically cleaned to remove loose scale and reinstalled in the furnace, and weight loss and percent weight loss determined. Test conditions were:

Corrodent - Air.

Time Increments for Weight Loss Determinations - 24, 96, 192, 288, 424, 536 and 686 hours.

Temperature - 2000 F.

Metals Tested - 25 Cr:20 Ni, 60 Cr:40 Ni and 50 Cr:50 Ni.

Specimen Dimensions -  $1/8"$  x  $5/32"$  x  $7/8"$ .

### Discussion and Results

Test specimen that could be salvaged from the porous, spongy section of 50 Cr:50 Ni casting were of dimensions  $1/8"$  x  $5/32"$  x  $7/8"$ . Similarly sized specimens were machined from control alloy 25 Cr:20 Ni and test alloys 60 Cr:40 Ni and 10 Al:90 Fe. Since this specimen size was greatly different from the usual  $2"$  x  $1"$  x  $1/4"$  or  $4"$  x  $1"$  x  $1/8"$  specimen sizes, 100 hour corrosivity vs. time tests were conducted instead of the usual tests of 5 hours or 20 hours duration.

An initial 100 hour test was conducted at 1700 F. using corrodents (a) 5 G. (15%  $\text{Na}_2\text{SO}_4$  + 85%  $\text{V}_2\text{O}_5$ ) and (b) 5 G. (90%  $\text{Na}_2\text{SO}_4$  + 10%  $\text{V}_2\text{O}_5$ ) + 2.14 G. Carbon. A suitable range of weight losses resulted for all alloys tested in high vanadium content mixture (a). However, high sodium sulfate-carbon bearing mixture (b) caused little corrosion to any of the alloys. Since number of test specimens was limited, the same specimens used in carbon bearing corrodent were subjected to another 100 hour test and corrodent weight was doubled to 10 G. (90%  $\text{Na}_2\text{SO}_4$  + 10%  $\text{V}_2\text{O}_5$ ) + 4.28 G. Carbon. This time sufficient corrosion resulted to afford comparison of the four alloys.

There appears to be a minimum quantity of reactants required to cause accelerated corrosion for system (90%  $\text{Na}_2\text{SO}_4$  + 10%  $\text{V}_2\text{O}_5$ ) + Carbon, the reason

for this phenomenon being unknown. Corrosion vs. time curves at 1700 F. are shown for the various alloys in high vanadium corrodent, Plate 3 and high sodium sulfate carbon bearing corrodent, Plate 4. Test data is listed in Table I below:

TABLE I

Corrodent - 5 G. (15%  $\text{Na}_2\text{SO}_4$ -85%  $\text{V}_2\text{O}_5$ ), Temperature - 1700 F.

Specimen Weight Loss - Percent

Time - Hours

<u>Alloy</u>	<u>1.0</u>	<u>2.5</u>	<u>4.0</u>	<u>6.0</u>	<u>22</u>	<u>46</u>	<u>70</u>	<u>100</u>
25 Cr:20 Ni	45.4	67.2	81.3	90.5	100	100	100	100
" " " "	--	--	79.2	87.4	100	100	100	100
60 Cr:40 Ni	7.9	9.5	12.4	17.3	33.2	59.2	71.5	87.1
50 Cr:50 Ni	7.2	9.9	13.7	17.1	35.4	60.4	94.3	100
10 Al:90 Fe	--	--	--	--	100	100	100	100

Corrodent - 10 G. (90%  $\text{Na}_2\text{SO}_4$ -10%  $\text{V}_2\text{O}_5$ ) + 4.3 G. Carbon,  
Temperature - 1700 F.

Specimen Weight Loss - Percent

Time - Hours

<u>Alloy</u>	<u>5</u>	<u>10</u>	<u>46</u>	<u>100</u>
25 Cr:20 Ni	100	100	100	100
" " " "	100	100	100	100
60 Cr:40 Ni	1.4	2.2	3.7	7.4
50 Cr:50 Ni	2.4	3.8	6.2	10.4
10 Al:90 Fe	55.0	63.1	70.1	72.5

Alloys 60 Cr:40 Ni and 50 Cr:50 Ni resist high vanadium attack much better than do alloys 25 Cr:20 Ni and 10 Al:90 Fe. Alloy 60 Cr:40 Ni is

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somewhat more resistant than 50 Cr:50 Ni. However, both alloys are severely attacked as time increases and corrosion vs. time relationship is approximately linear. The test specimens after descaling are shown in Plate 1.

Corrosion resistance of 60 Cr:40 Ni and 50 Cr:50 Ni alloys to attack caused by the high sodium sulfate carbon bearing corrodent is excellent. Alloys 25 Cr:20 Ni and 10 Al:90 Fe suffer catastrophic attack in short periods of time in this type corrodent. Specimens of 25 Cr:20 Ni alloy were completely consumed during the first five hours of test. Plateau of curve for 10 Al:90 Fe alloy after approximately ten hours is typical for carbon bearing corrodents and represents time at which corrosive sodium sulfide is depleted. Alloy 60 Cr:40 Ni again appears slightly more resistant than 50 Cr:50 Ni. The test specimens after descaling are shown in Plate 2.

Alloys 60 Cr:40 Ni and 50 Cr:50 Ni evidenced corrosion patterns similar to those of 25 Cr:20 Ni alloy in both types of corrodent. In high vanadium corrodent metal surfaces were substantially smooth and uniform as though metals were being dissolved. However, in high sodium sulfate carbon bearing mixture, corrosive attack was more localized with heavy pitting in some cases. The 10 Al:90 Fe alloy was consumed by high vanadium corrodent and suffered severe penetration and embrittlement in high sodium sulfate carbon bearing mixture in relatively short periods of time.

A prolonged air oxidation test was conducted at 2000 F. to compare relative high temperature scaling resistance of alloys 25 Cr:20 Ni, 60 Cr:40 Ni and 50 Cr:50 Ni. Test was run for 685 hours. Curves of percent weight loss vs. time in Plate 5 show 60 Cr:40 Ni to have best resistance to high temperature scaling with 50 Cr:50 Ni next best and 25 Cr:20 Ni alloy third. Test data is listed below, Table II.

TABLE II

Corrodent - Air; Temperature - 2000 F.

Specimen Weight Loss - Percent

<u>Alloy</u>	<u>Time - Hours</u>						
	<u>24</u>	<u>96</u>	<u>192</u>	<u>288</u>	<u>424</u>	<u>536</u>	<u>686</u>
25 Cr:20 Ni	0.2	0.9	2.0	2.3	4.1	12.6	14.1
60 Cr:40 Ni	0.4	1.0	1.3	1.4	1.7	2.1	2.4
50 Cr:50 Ni	0.7	2.1	3.7	4.3	5.4	6.3	6.7

It is of interest to note that 25 Cr:20 Ni alloy shows less scaling up to 424 hours than does 50 Cr:50 Ni alloy, then in the next time increment shows excessive scaling after which curve again assumes its previous slope. Visual observations of the test specimen substantiated the experimental data since it was noticed that at 460 hour time increment a thick oxide coating appeared from the 25 Cr:20 Ni specimen.

Conclusions

- a. Alloys 60 Cr:40 Ni and 50 Cr:50 Ni are superior to 25 Cr:20 Ni alloy in high temperature corrosion resistance to synthetic fuel oil ash residues. They are extremely resistant to sulfide attack caused by carbon bearing corrodents of high sodium sulfate content. They are considerably more resistant to corrodents of high vanadium content than is 25 Cr:20 Ni alloy.
- b. Alloy 60 Cr:40 Ni is considered to have somewhat better corrosion resistance than alloy 50 Cr:50 Ni.
- c. These alloys also have better resistance to high temperature scaling than does 25 Cr:20 Ni alloy. Alloy 60 Cr:40 Ni is more resistant than alloy 50 Cr:50 Ni.
- d. Alloy 10 Al:90 Fe has inferior high temperature corrosion

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Recommendations

1. It is recommended that:
  - a. "Dog bone" type superheater support elements be fabricated from 80 Cr:20 Ni alloys and that those parts be service tested.
  - b. Alloy 10 Al:90 Fe be considered unsuitable for naval use in highly corrosive environments at elevated temperatures.

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CRUCIBLE TESTS

SPECIMENS AFTER DESCALING

TEMP 1700°F

CORRODENT 5 G 10% H<sub>2</sub>SO<sub>4</sub> BEV OF

INITIAL SPECIMEN SIZE 7/8" X 5/32" X 1/8"

























TIME HRS.	25 Cr. 20 Ni	60 Cr. 40 Ni	50 Cr. 50 Ni
1			
2.5			
4			
6			
22			
46			
70			
100			

PLATE 1

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CRUCIBLE TESTS

SPECIMENS AFTER DESCALING

TEMP. 1700°F

CORRODENT 10G. (90%  $\text{Na}_2\text{SO}_4$ , 10%  $\text{V}_2\text{O}_5$ ) + 4.3 G. CARBON

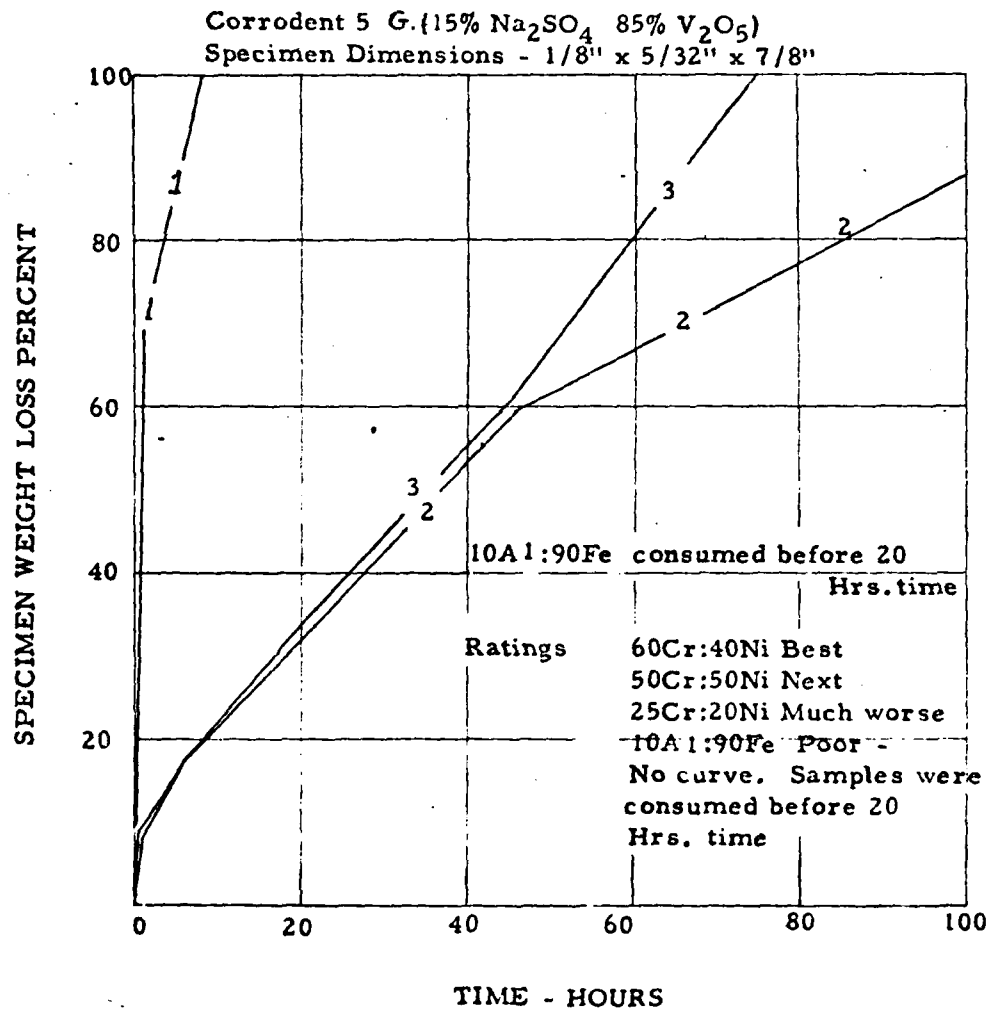
INITIAL SPECIMEN SIZE 7/8" X 5/32" X 1/8"

TIME HRS.	25 Cr 20 Ni	60 Cr 40 Ni	50 Cr 50 Ni	10AL 90FE
5				
10				
46				
100				

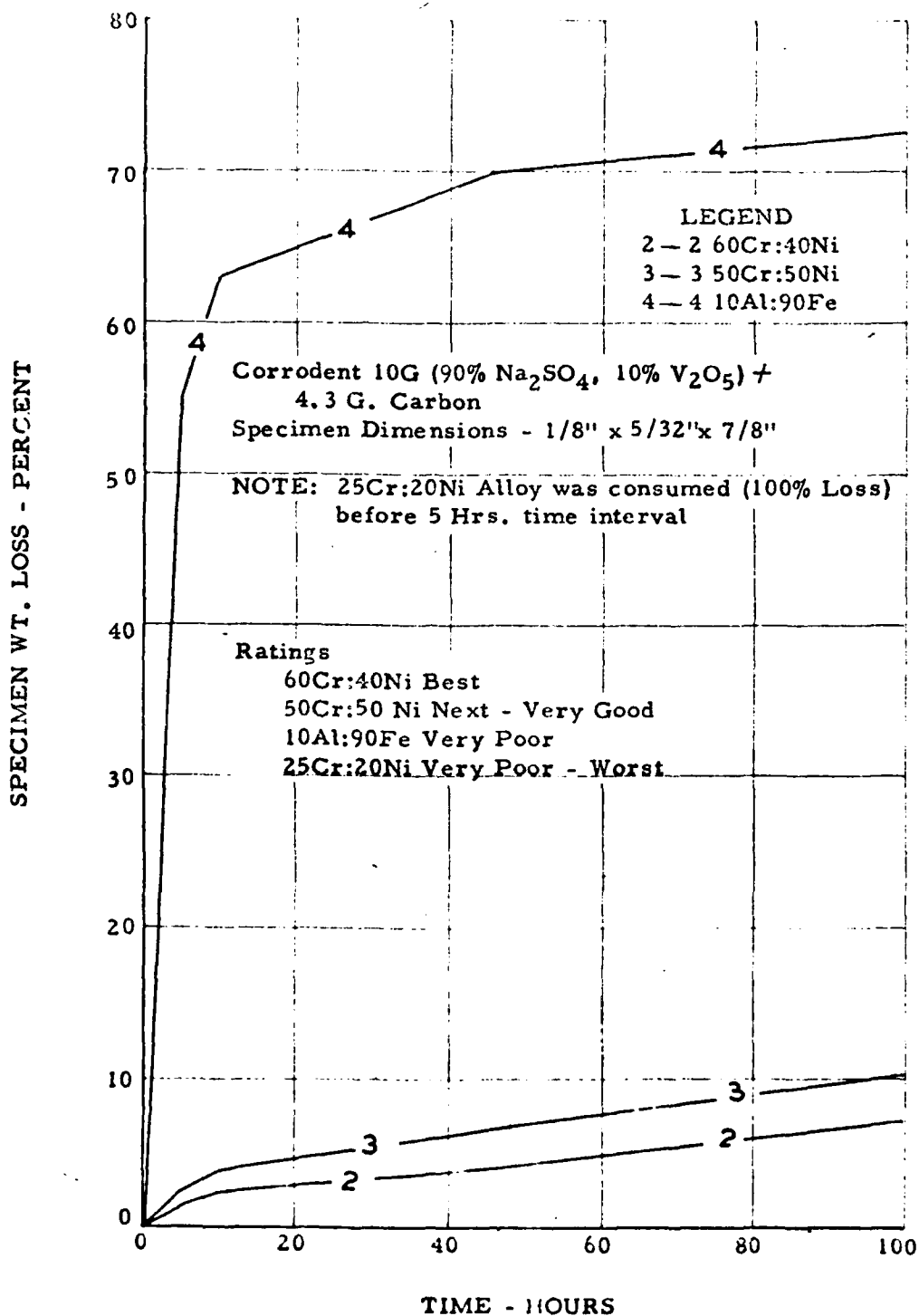
Crucible Corrosion Tests of Alloys 25Cr:20Ni,  
60 Cr:40Ni, 50Cr:50Ni and 10Al:90Fe in High  
Vanadium-Corroddent

LEGEND

- 1—1 25Cr:20Ni
- 2—2 60Cr:40Ni
- 3—3 50Cr:50Ni



Crucible Corrosion Tests of Alloys 25Cr:20 Ni, 60Cr:40Ni, 50Cr:50Ni and 10 Al:90Fe in High Sodium Sulfate Carbon Bearing Corrodent



AIR OXIDATION OF REFRACTORY ALLOYS AT 2000 F

